MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

EMF4096 – RADAR SYSTEMS DESIGN AND ANALYSIS

(TE & MCE)

9 MARCH 2016
Time: 9 am – 11 am
(2 Hours)

INSTRUCTION TO STUDENTS

1. This question paper consists of 5 pages including cover page with 4 questions only.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the answer booklet provided.

Question 1

(a) Explain briefly the meaning of the following terms as applied in a radar system:

(i) Range resolution, and

[2 marks]

(ii) Pulse repetition frequency (*PRF*).

[2 marks]

(b) An *X*-band (10 GHz) pulse radar has a pulse repetition frequency of 5 kHz. It is to be used for operation in an air traffic control tower covering a maximum range of not less than 50 km and should be able to detect aircraft speeds of up to 50 m/s. Determine whether this radar will encounter range and/or Doppler ambiguity or not.

[8 marks]

(c) (i) *L*-band (1.2 GHz) radar is to be designed for operation in an air traffic control tower. The radar should have a minimum unambiguous range of 30 km. Determine the highest pulse repetition frequency (*PRF*) that can be set for this radar?

[2 marks]

(ii) For pulse repetition frequency (*PRF*) in (i) above, determine the maximum radial velocity that can be measured if Doppler ambiguity must be avoided.

[2 marks]

(iii) The above radar is required to have a range resolution of 75 m. Determine the pulse width required and the corresponding duty cycle.

[3 marks]

(iv) The other parameters of the radar is given as:

Losses, $L = 3$ dB.

Noise figure, $F = 3$ dB.

If the minimum target cross section (*RCS*) that must be detected is 1 m^2 and the available maximum transmitted power is 10 MW. Determine the minimum gain if minimum signal-to-noise ratio (*SNR*) for detection is 15 dB.

[Given Boltzmann's constant, $k = 1.38 \times 10^{-23}$ J/K and ambient temperature, $T = 290$ K].

[6 marks]

Continued...

Question 2

(a) Briefly discuss the tracking of satellite from an earth station.

[8 marks]

(b)

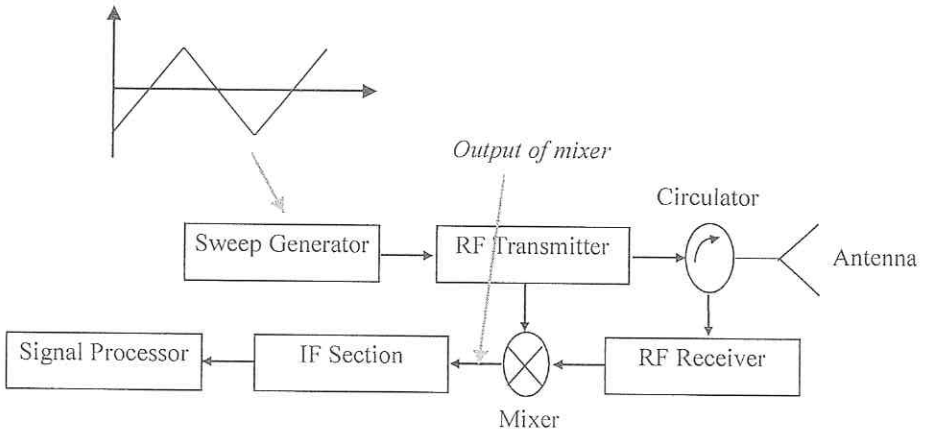

Fig. Q2(b)

Consider Frequency Modulation Continuous Wave (*FM-CW*) radar with a linear *FM* modulation as shown in Fig. Q2(b). The modulating frequency is 1.57 kHz, the bandwidth is 180 kHz and the center frequency is 2.4 GHz. The radar detects a target moving away from the radar, at a range of 40 km with a velocity of 120 m/s.

(i) Compute the frequencies present at the output of the mixer.

[7 marks]

(ii) Draw the return echo of the linear *FM* signal (frequency vs. time). On your drawing, show the relative position of the transmitted signal.

[3 marks]

(c) Fig. Q2(c) shows a single delay line canceller used in Moving Target Indicator (*MTI*) filter.

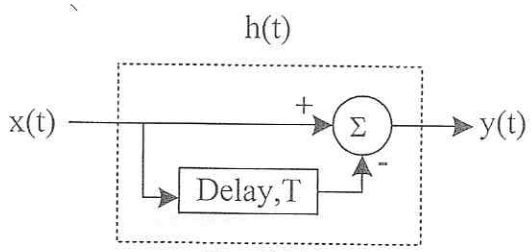

Fig. Q2(c)

The canceller's impulse function is denoted as *h(t)*, input is *x(t)* and output is *y(t)*. Delay *T* is equal to the inter pulse period (*IPP*) of the radar. Prove the power gain of the canceller is given by $4[\sin(\omega T/2)]^2$.

[7 marks]

Continued...

Question 3

(a) Radar cross section (*RCS*) of sea waves can be modeled with the log-normal probability distribution function (*PDF*). It is given that the standard deviation (ρ_s) and median value of a sea wave clutter's *RCS* (σ_m) are 2.5 and 0.06, respectively. Determine the probability of getting *RCS* return amplitude (a_s) 1.1 V ± 1 %. Log-normal *PDF* for amplitude(a_s) is given by

$$p(a_s) = \frac{1}{a_s \rho_s} \sqrt{\frac{2}{\pi}} e^{-\{(2lna_s - ln\sigma_m)^2 / 2\rho_s^2\}}$$

[8 marks]

(b) Compute the signal-to-clutter ratio (*SCR*) for a radar with the following specifications:
Antenna 3 dB beam width, θ_{3dB} = 0.022 rad, pulse width, τ = 10 μs, range, R = 25 km, and grazing angle, ψ_g = 53°. The target *RCS*, σ_t is 0.5 m^2 and surface clutter reflection coefficient, σ^0 = 0.01.

[5 marks]

(c) Ground based radar operates at a frequency of 1.5 GHz. A complex object appears in the footprint of the radar with three identical scattering centers as shown in Fig. Q3(c), equally spaced at 1.21 m from each other. The radar cross section (*RCS*) of the scattering center (σ) is independent of the aspect angle and equal to -10 dB.

(i) Compute the effective *RCS* (σ_{eff}) in dB.

[6 marks]

(ii) If the points are rotated by 30 degree from the line of sight, determine the effect on the effective *RCS*.

[6 marks]

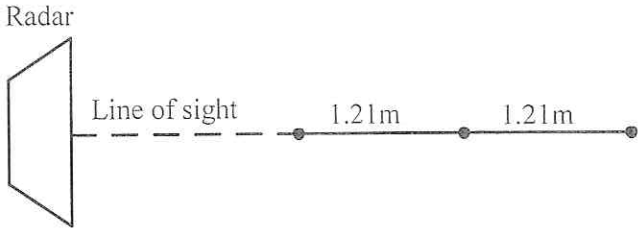

Fig. Q3(c)

Continued...

Question 4

(a) Describe **FOUR** (4) types of STAble Local Oscillator (*STALO*) used in radar system.

[4 marks]

(b) Compare the performance of the electromechanical switch and pin-diode switch by completing the following table:

	Electromechanical Switch	**Pin-diode Switch**
Insertion loss		
Isolation		
SWR		
Switching time		

[6 marks]

(c) Fig. Q4(c) shows the block diagram of airborne synthetic aperture radar (*SAR*) system.

(i) Elaborate the main purpose of using circulator in this system?

[3 marks]

(ii) Describe **ONE** (1) disadvantage of the circulator if high power signal is transmitted? Propose a possible solution to overcome this disadvantage and draw an appropriate figure to illustrate your proposal.

[3+4 marks]

(iii) Describe the main objective of Low Noise Amplifier (*LNA*) in the receiver?

[3 marks]

(iv) Illustrate the main function of the 100 MHz oscillator in this design?

[2 marks]

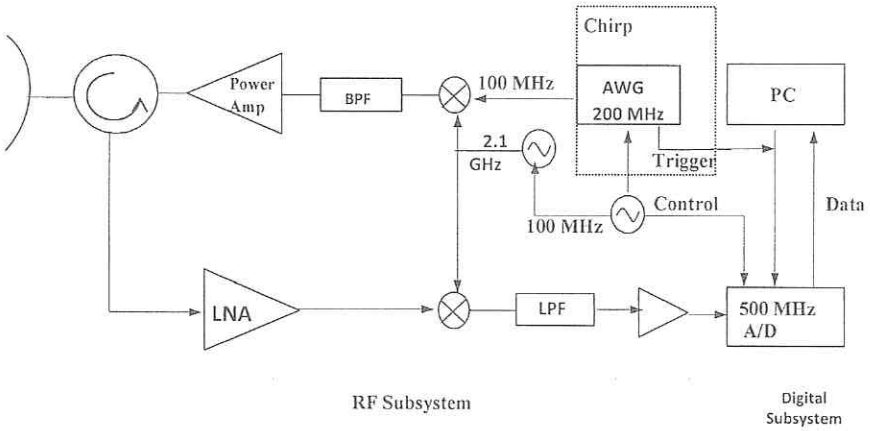

Fig. Q4(c)

End of Paper